MULTI-BUNCH INTEGRATED ILC SIMULATIONS

Glen White, SLAC/QMUL

Snowmass 2005

Multi-Bunch ILC Simulations

- Generate a representation of the ILC bunch train at a ‘snapshot’ in time to study the ILC machine Luminosity performance with ground motion and other error sources for different machine parameters.
- Track 600 bunches through Linac, BDS and IP to observe dynamics of fast feedback correction (IP position and angle) + Lumi feedback and determine estimate of train luminosity.
- Use PLACET for Linac simulation and MatMerlin for BDS (GUINEA-PIG used for IP collision).
- Model case of tuned lattice + 1 pulse of GM (Linac + BDS).
- TESLA TDR & ILC IR-1 (20mrad IP x-ing) BDS currently implemented.
- Typical simulation times 60 hours+ depending on simulation parameters (per seed).
- To gauge performance for a variety of parameters/simulation environments/machines need many CPU hours.

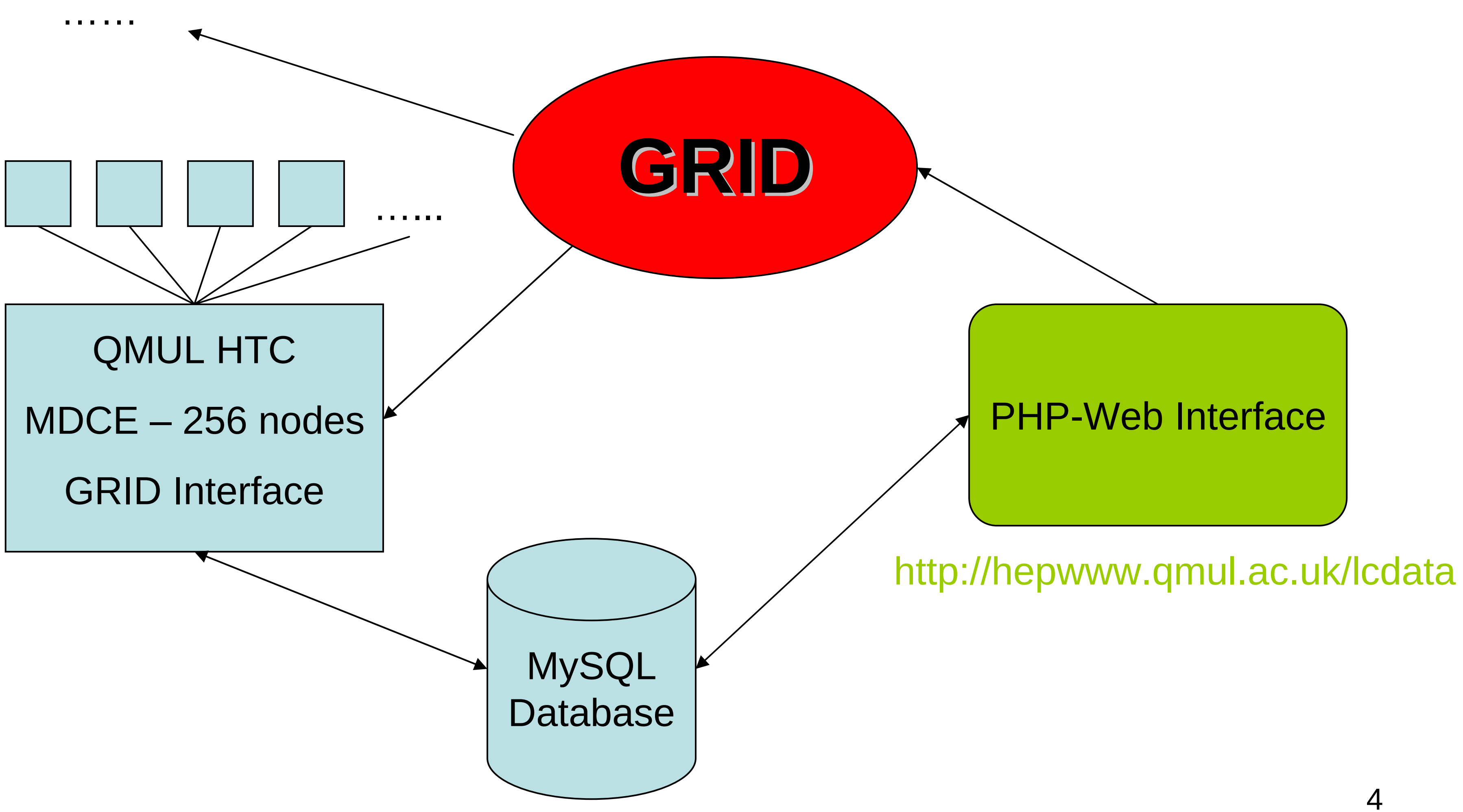
QMUL High-Throughput Cluster

•QMUL Test GRID cluster- http://194.36.10.1/cluster

•QMUL high-throughput cluster: GRID cluster development. Currently 348 CPUs (128 dual 2.8 GHz Intel Xeon nodes with 2 GB RAM and 32 dual 2.0 GHz AMD Athlon nodes with 1 GB RAM) . Total available storage of 40TB. 1 Gb internal networking and 1Gb bandwidth to London MAN.

•Will upgrade by 2007 to ~ 600CPUs and 100TB storage which will be mainly used for LHC computing needs.

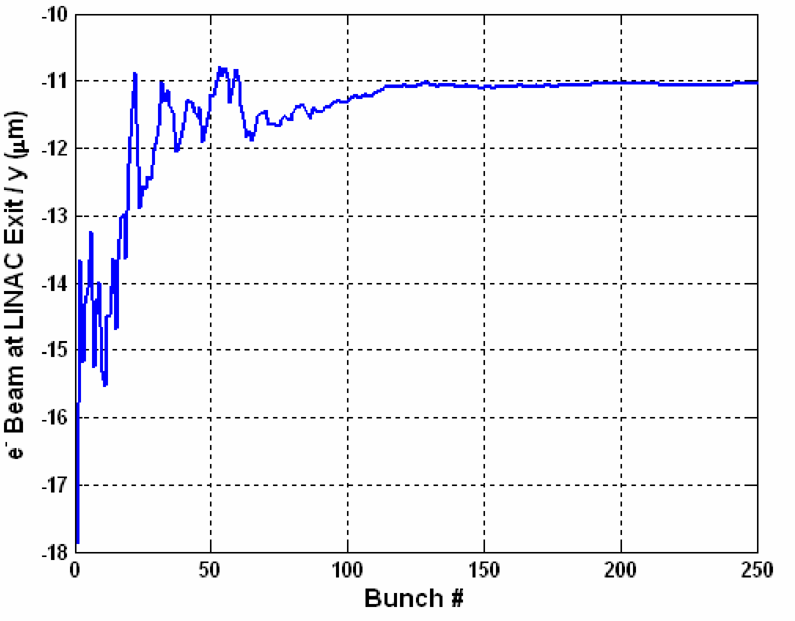
Parallel Computing Infrastructure



Linac Simulation

PLACET:

- **Train enters linac with 20nm vertical emittance.**
- **Structure Misalignment: 0.5mm RMS y, 0.3mrad y' error.**
- **Long- and short-range transverse and longitudinal wakefield functions included.**
- **BPM misalignment: 25um (y).**
- **Apply 1-1 steering algorithm.**
- **Pick random seed which gives 50% emittance growth .**
- **Apply y, y' RMS Injection error.**
- **Apply Inter-Train Ground Motion (K-Model).**
- **Generate 600 bunches (multiple random seeds).**



- **Long-range wakes have strong effect on bunch train.**
- **Need to perform steering on <u>plateau</u> not first bunch.**

BDS/IP Simulation

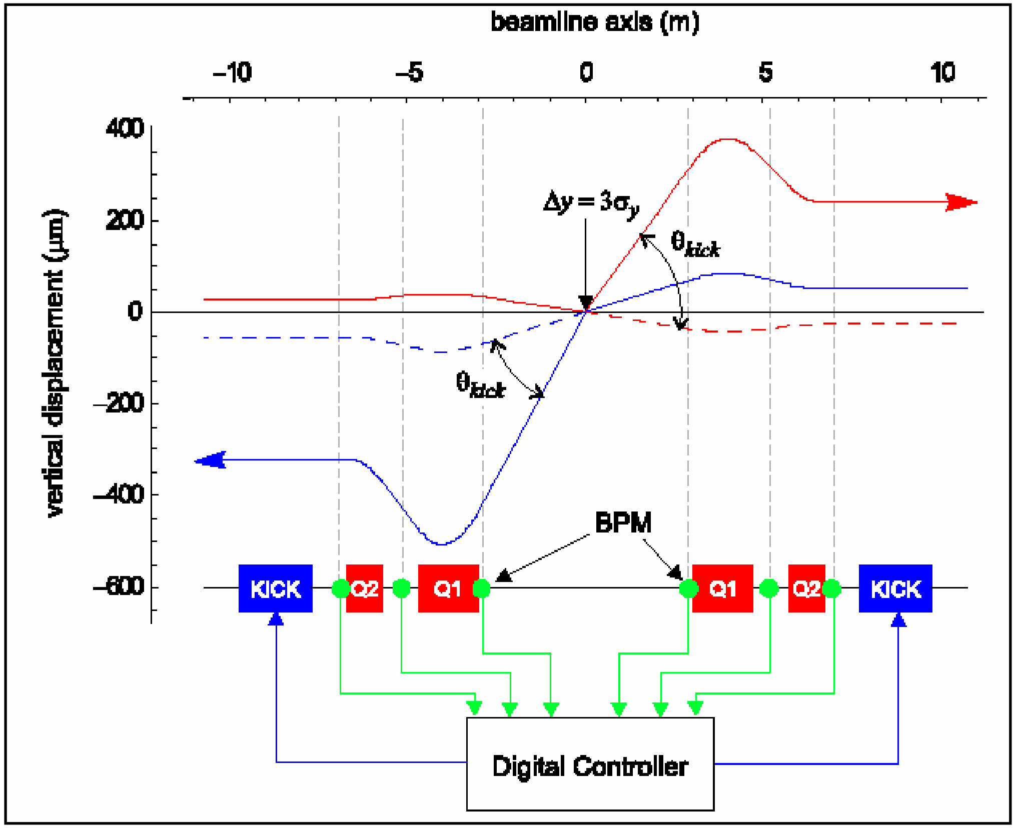
MATMERLIN:

- **Inter-Train Ground motion applied (K-model).**
- **Add 1.4ppm energy jitter on e^- bunches (simulates passage of e^-'s through undulator).**
- **Track 80,000 macro-particles per bunch.**

- **Feedback (Simulink model in Matlab):**
  - **BPM Resolution: 2μm (ANG FB) 5μm (IP FB)**
  - **Kicker errors: 0.1% RMS bunch-bunch.**

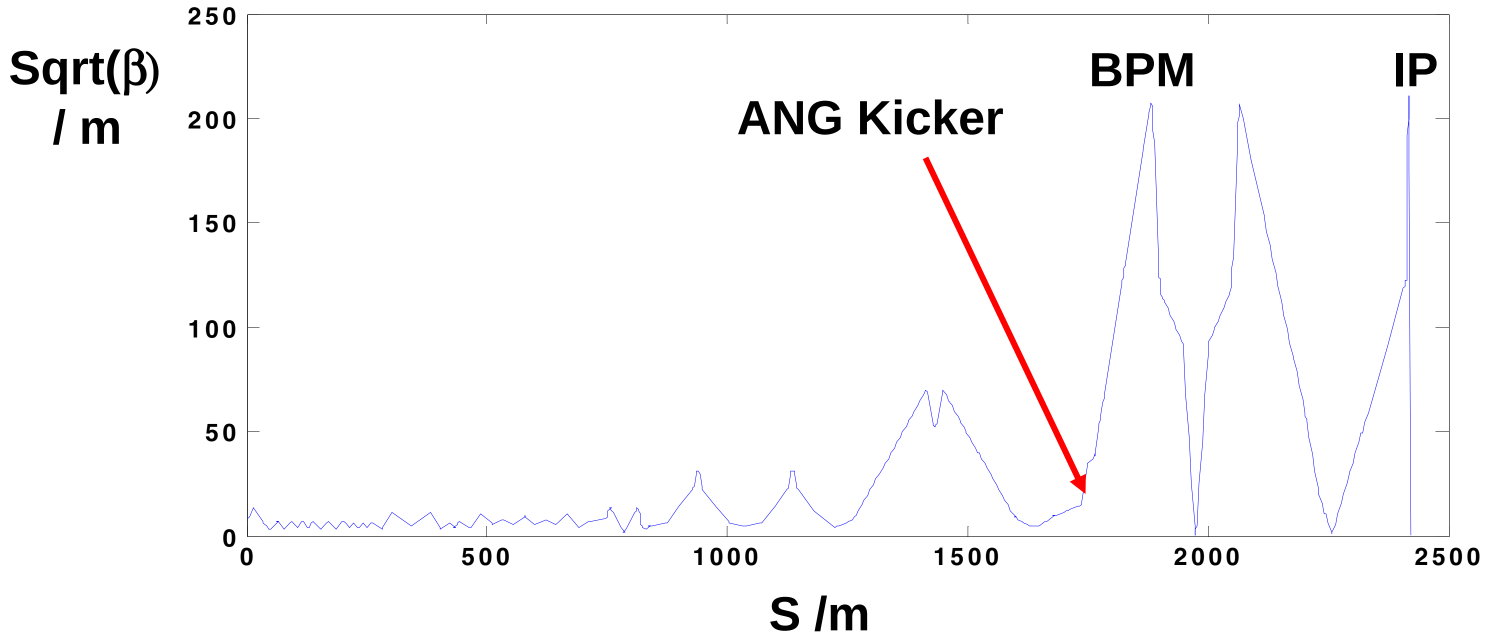
- **IP (Guinea-Pig):**
  - **Input macro-beam from MatMerlin BDS (non-gaussian).**
  - **Calculates Lumi & Beam-Beam kick.**
  - **Produces e^+e^- pairs -> track through solenoid field and count number hitting LCAL first layer for Lumi FB signal.**

IP Fast Feedback System



- Detect beam-beam kick with BPM(s) either side of IP.
- Feed signal through digital feedback controller to fast strip-line kickers either side of IP.
- Digital PI control algorithm is used for feedback algorithm.

IP-Angle Feedback System

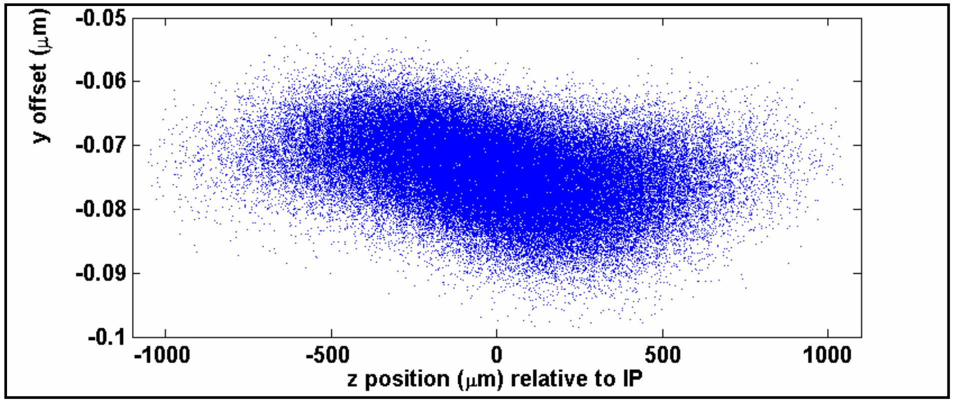


- Place kicker at point with relatively high β function and at IP phase.
- BPM at phase 90^0 downstream from kicker.
- To cancel angular offset at IP to $0.1\sigma_{y'}$ level :
  - BPM required resolution ~ 2um
  - FB latency = 4 bunches.
- Other FB locations possible:
  - Start of BDS to act as a pulse-flattener to reduce orbit error
  - Requires ~100nm BPM resolution with these optics.

Banana Bunches

•**Short-range wakefields in accelerating cavities acting back on bunches cause systematic shape distortions:**

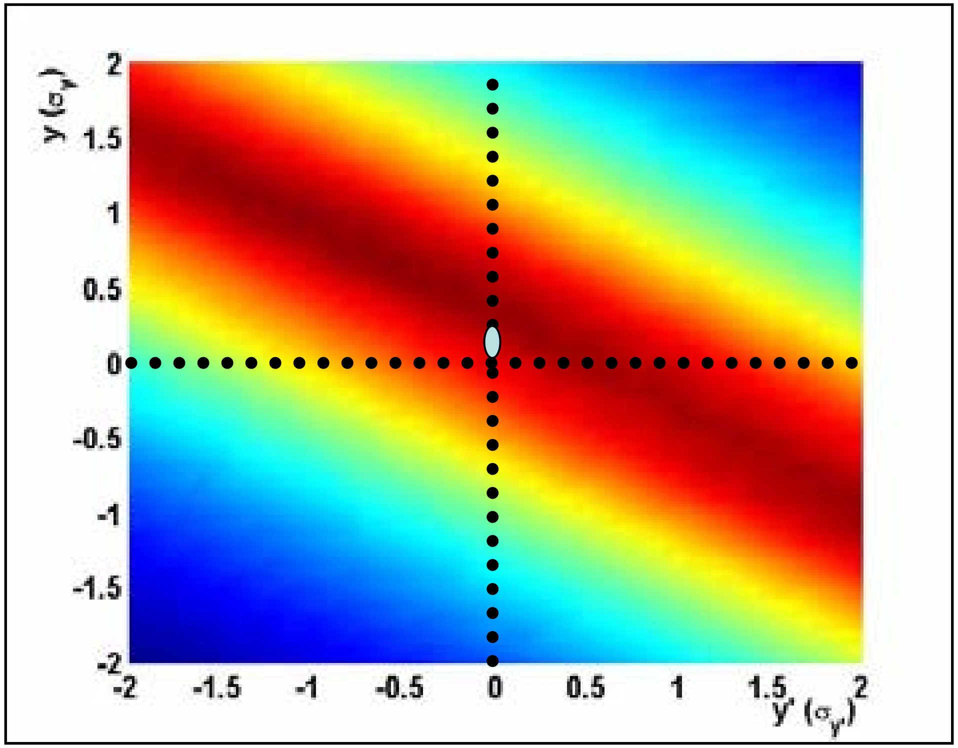
- **Z-Y plane of a sample bunch:**



•**Only small increase in vertical emittance, but large loss in luminosity performance with head-on collisions due to strong, non-linear beam-beam interaction.**

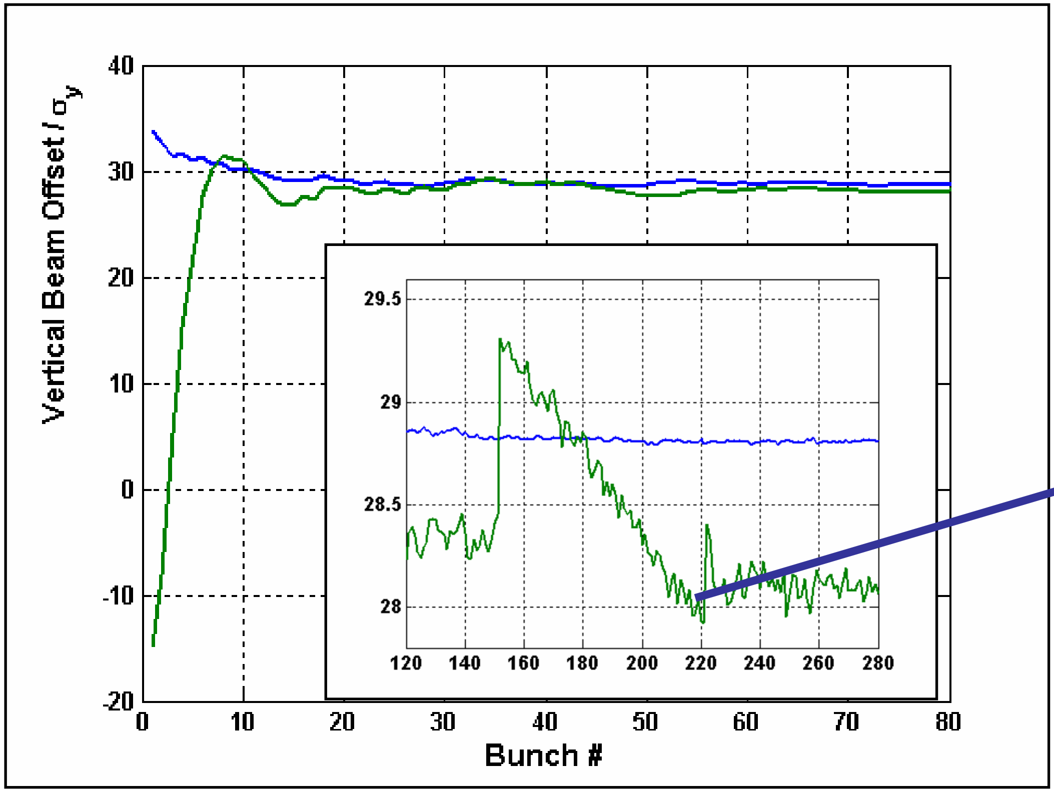
•**Change in beam-beam dynamics from Gaussian bunches.**

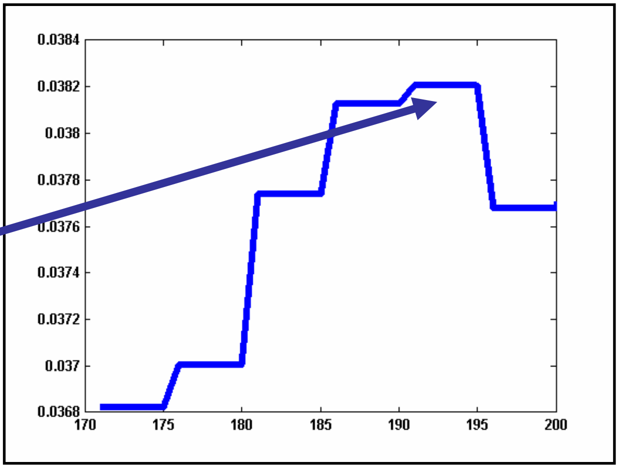
Banana-Bunch Dynamics



- Luminosity of a sample bunch over range of position and angle offsets.
- Feedback strategy: wait for IP and ANG FB systems to ‘zero’ (coloured ellipse in figure)– then fine tune by stepping in y then y’ using LUMI monitor (count e^+e^- hits in first layer of BeamCal) to find optimum collision conditions.

IP Feedback

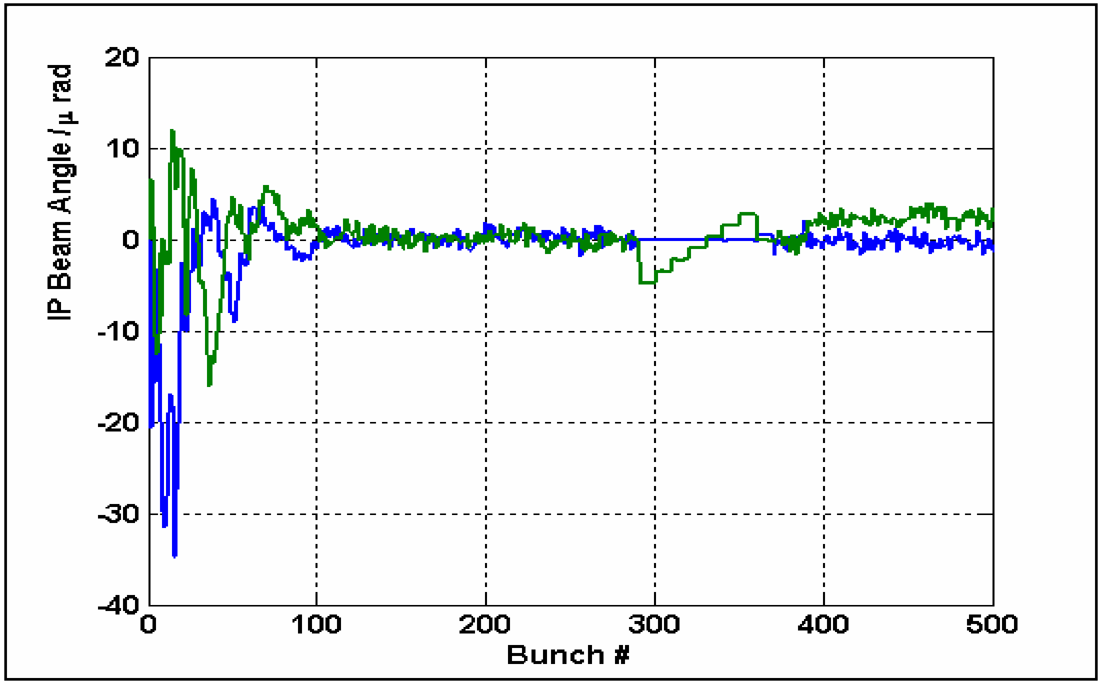




5 Bunch e^+e^- Int. Signal

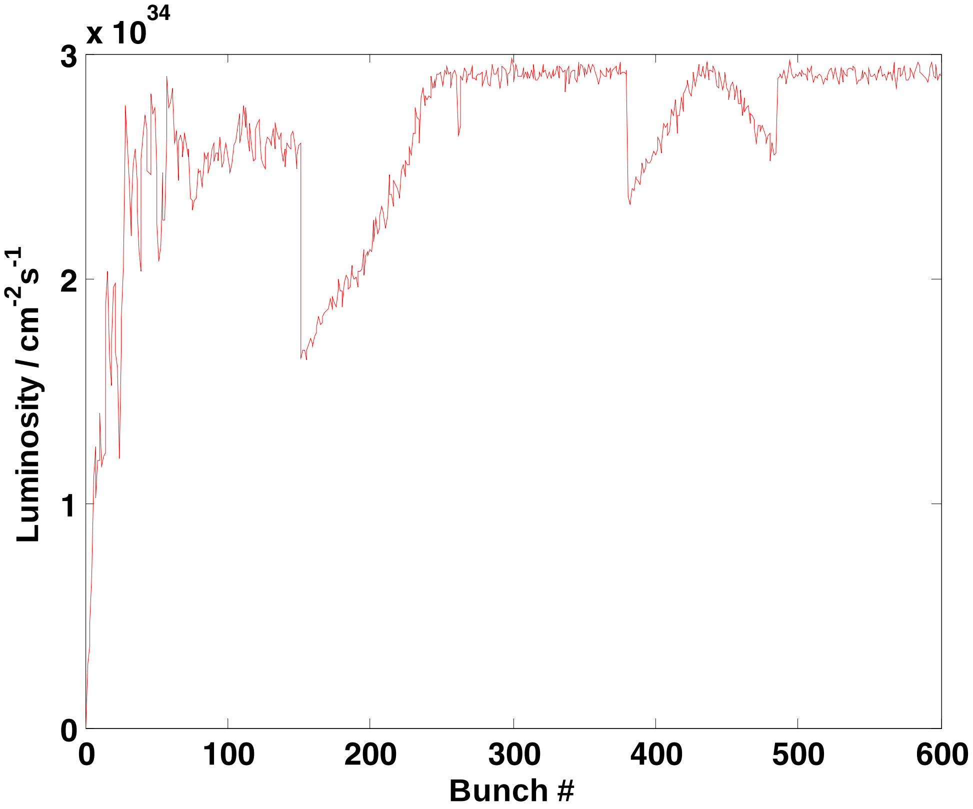
- **Single example seed shown.**
- **Corrects < 10 bunches.**
- **Corrects to finite Δy due to banana bunch effect.**
- **Vertical Beam-Beam scan @ bunch 150.**

Angle Feedback



- Single example seed shown.
- Angle scan after 250 bunches when position scan complete.
- Noisy for first ~100 bunches (HOM's).
- FB corrects to <0.1 $\sigma_{y'}$.

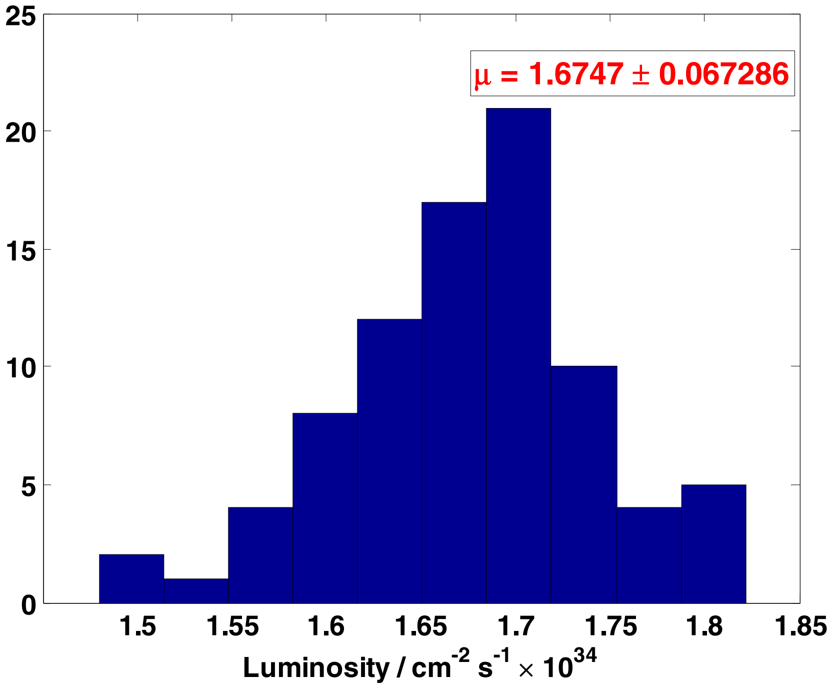
Luminosity

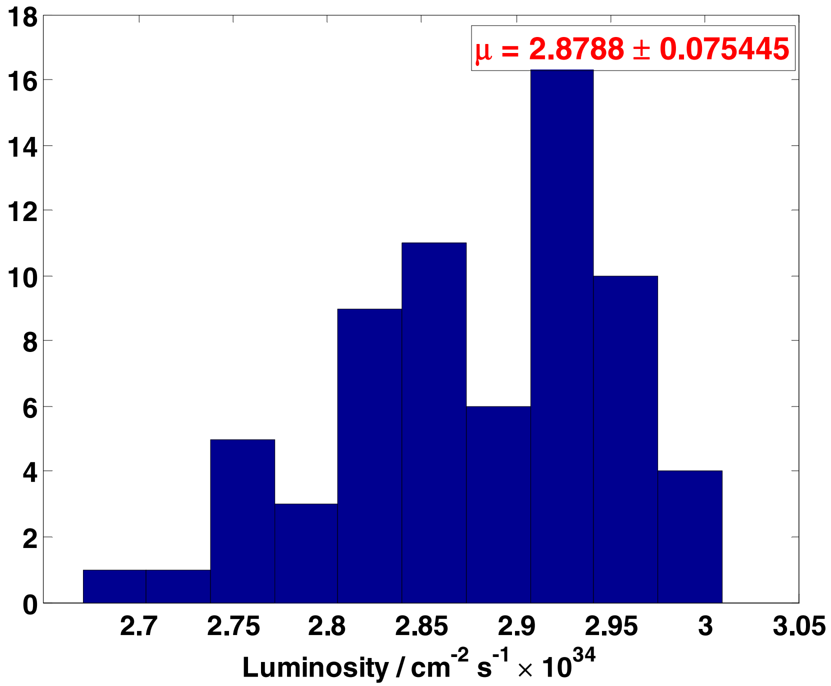


•Luminosity through example seed bunch train showing effects of position/angle scans.

•Total luminosity estimate: L(1-600) + L(550-600)*(2820-600)/50

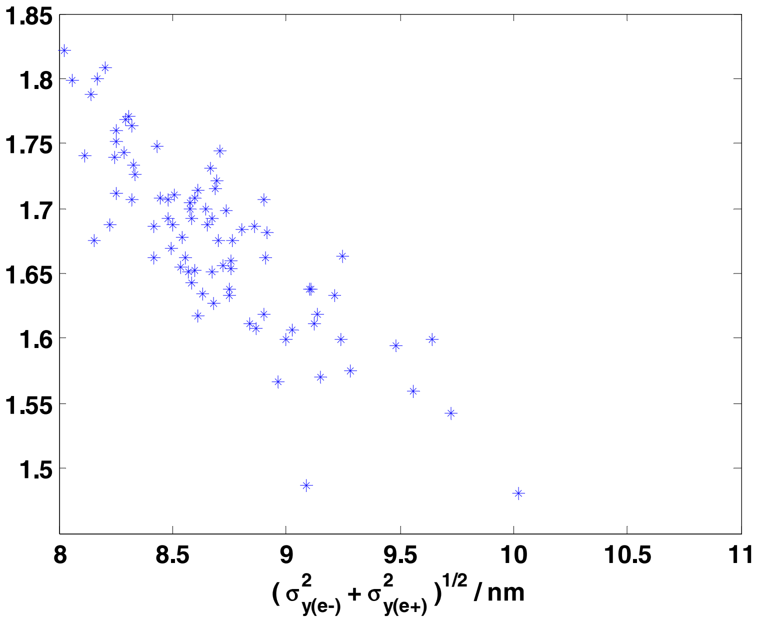
Luminosity – 100 Seeds



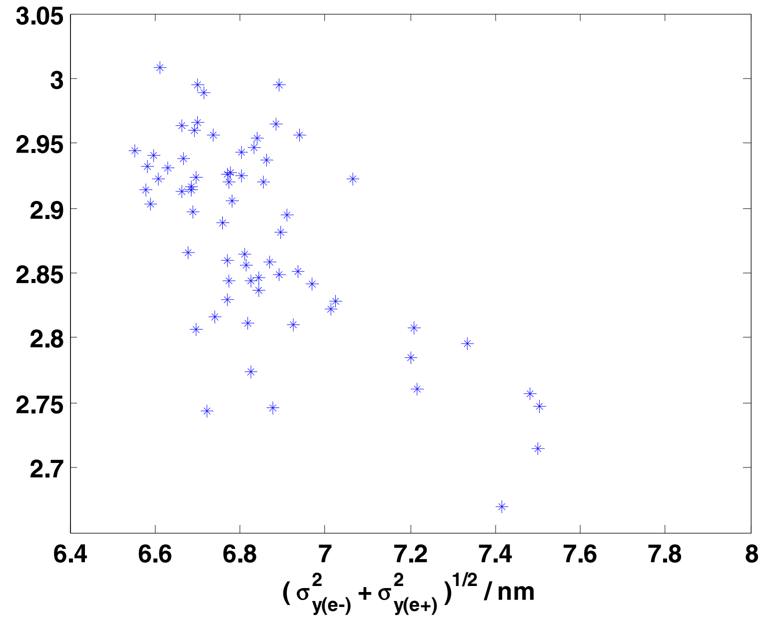


- **ILC-IR1 350 GeV (left) 500 GeV (right) CME.**
- **No improvement seen with addition of upstream FFB system.**

Luminosity vs. IP Beam Size



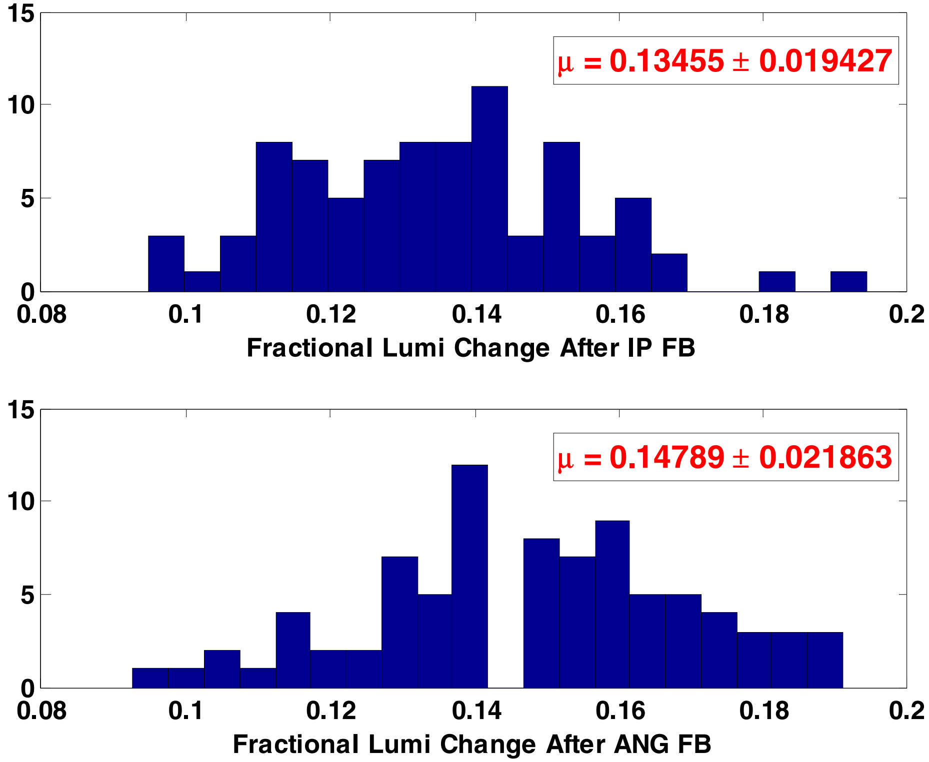
350 GeV CME



500 GeV CME

- **Lumi not directly proportional to IP beam spot size due to banana-beam effect.**

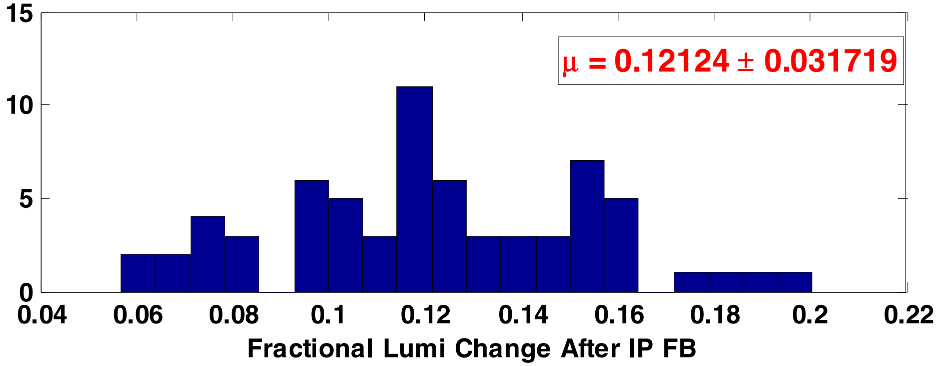
Effect of Lumi-Scan (350 GeV)



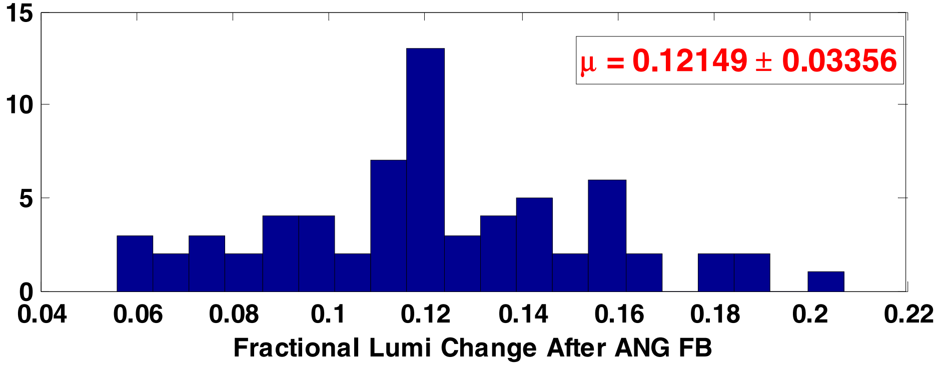
- After position scan
- After position and angle scan

- Effect of Pos & Ang Lumi scans compared with start of pulse with FB only.
- Angle feedback gives some improvement.

Effect of Lumi-Scan (500 GeV)



•After position scan

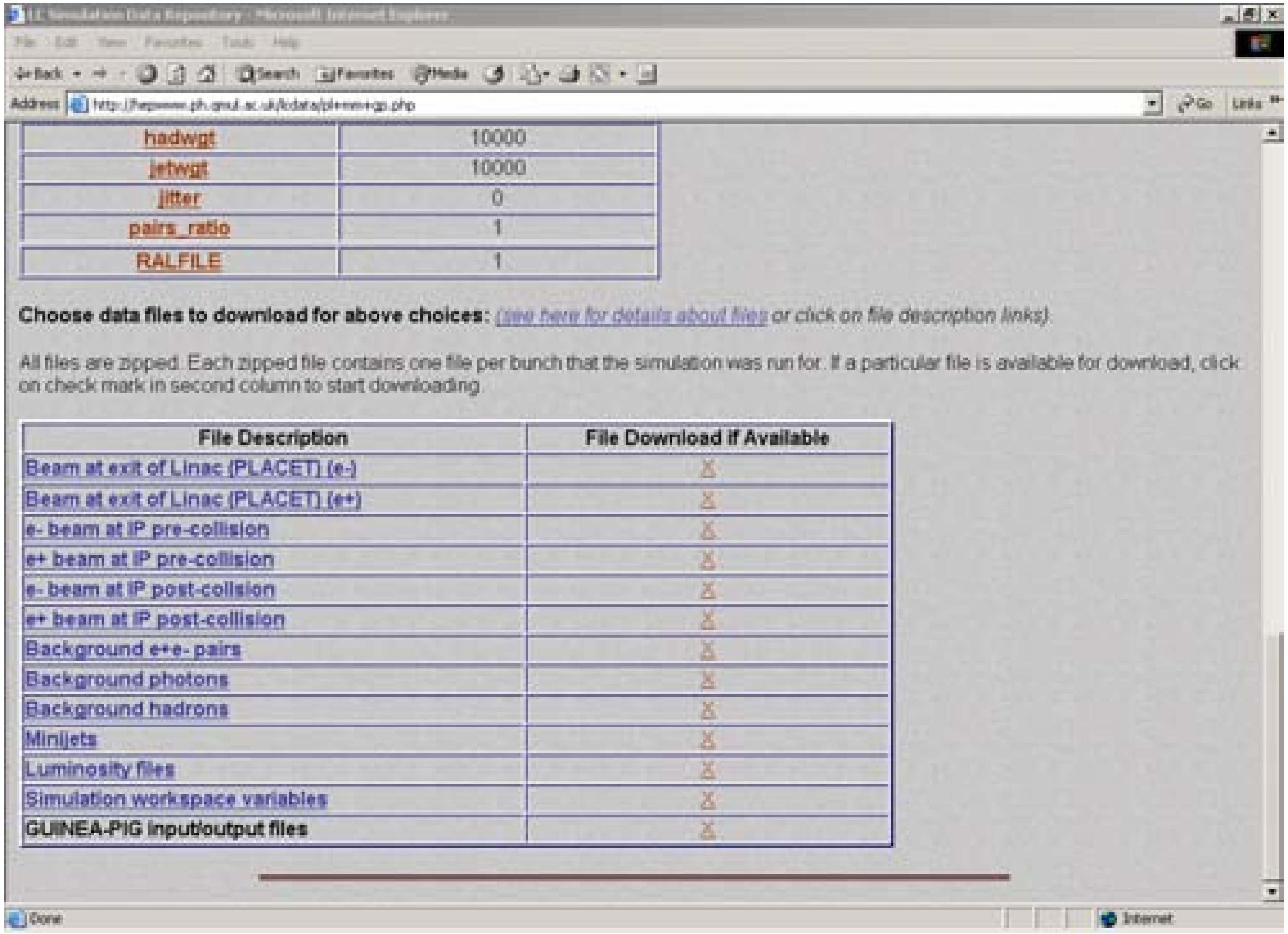


•After position and angle scan

•Effect of Pos & Ang Lumi scans compared with start of pulse with FB only.

•Angle feedback gives only small improvement.

ILC Simulation Web Page



- Store all beam data from simulation runs online
- http://hepwww.ph.qmul.ac.uk/lcdata

Summary and Plans

- Facility for parallel processing of accelerator codes set-up.
- Shown here to test ILC performance with Fast-Feedback.
- Final luminosity performance appears to be limited by banana-bunch shape.
- Add full Linac + BDS alignment and inter-pulse feedback to provide full time-evolved simulation.
- Add Crab Cavities to study crossing angle stability (requires addition of x-feedback)
- Other lattices + Beam Parameters (@350, 500 & 1000 GeV).
- Add Collimator Wakes.